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GPS based Multi-hop Communication with Localization in Subterranean Wireless Sensor Networks

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Abstract

Our research work proposes Multi-hop Communication with Localization (MCL), a strategy to localize and route information to nodes present in such areas by determining angles and distances of consecutive nodes hop by hop towards the Base Station. Based on the application area, Subterranean Wireless Sensor Networks are specifically designed to detect underground abnormal conditions and reported to the base station. Many protocols use distance between the nodes as one of the criteria for multi-hop communication in the network. It is found to be necessary to know the location of the nodes and the distance between the nodes in many power optimization protocols. But the query of how to attain the distance or the location arises in the same. The main objective here is to design a technique to both localize and transmit data efficiently in subterranean areas. Initially there is a group of nodes deployed in the underground areas all of which bond to a sink that is further connected to the Base Station. It is possible to locate all the nodes through GPS which can be used as a reference in the worst case scenario by the Base Station. The sink node has a Node Transmission Area (NTA) within which a node can be directly recognized by the sink node otherwise it finds the target node through the intermediate nodes. Our empirical work proves the computational method on attaining the performance.

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Keywords: Wireless Sensor Networks, subterranean, localization, target, angle;

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1. Introduction

Most wireless communication is hardly possible due to the difficulty in the penetration of wireless signals in underground areas. However, this challenge needs to be overcome by the co-operative process of the underground sensors operating together in a network. Wireless Sensor Networks have been used in a many areas right from domestic to industrial areas. Industrial Monitoring and Control have found the applications of wireless sensors very productive, while subterranean areas have been attacked by terrorists in the recent past which have exposed the vulnerability of underground areas as shown in Fig. 1 After the London Underground explosion (2005), the usage of WSNs underground has been implemented and is still under current research. There is absolute need to localize and route information through the wireless nodes present in subterranean areas. Hence the need to monitor underground areas has increased greatly.

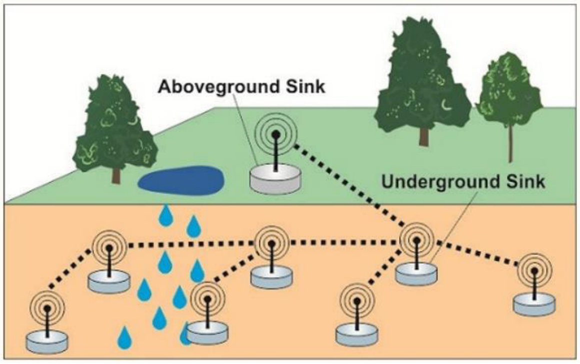

Fig.1. Usage of wireless underground sensor networks for agricultural monitoring [a]

Some of the basic assumptions in the Subterranean Wireless Sensor Networks are:

- All nodes are below the ground level and there is interference present
- There is a central receiver or a sink that reports to a control room or a base station
- The wireless underground sensors are randomly deployed underground within transmissible range of each other.

A number of localization methods are available to detect and localize target nodes in the literature. However, there is the need to investigate techniques that can provide greater accuracy in localizing wireless nodes while communication is performed as well. Beacon based communication can be performed to efficiently localize and communicate with nodes in the network. Methods to perform localization exist in the literature that can provide more than 50% accuracy. However, this is a different approach that explores to send data with greater efficiency wherein localization is an important subpart. In this work, a protocol that can efficiently localize and facilitate communication in the wireless underground sensor networks is proposed, simulated and validated. The remaining sections include related works, description of the proposed method and simulation analysis.

2. Related Work

A number of works are available pertaining to the localization of a node in a wireless sensor network. Few unsolvable methods not only remain as a motivation for this work is proposed.

2.1 Global Positioning System (GPS)

Sensors with known location information are called anchors and their locations can be obtained by using a global positioning system (GPS). These anchors will determine the location of the sensor network in the global coordinate system. Location of a GPS satellite at any particular time instant is known. GPS receiver located on the earth derives its distance to a GPS satellite from the difference of the time a GPS signal is received at the receiver and the time the GPS signal is radiated by the GPS satellite. Capkun., et al (2001) explained the GPS disadvantages are expensive, cannot used by the indoors, confused by tall buildings or other environmental obstacles. GPS receivers also consume significant battery power which can be a problem for power-constrained sensor nodes.

2.2 Received Signal Strength (RSS)

Bahl and Padmanabhan (2000) proposed that each non-anchor node, unaware of its location, uses the signal strength measurements it collects stemming from the anchor nodes within its sensing region and creates its own Received Signal Strength (RSS) finger print which is transmitted to the central station. After that the central station matches the presented signal strength vector to the RSS using probabilistic techniques or some kind of nearest neighbour-based method which chooses the location of a sample point whose RSS vector is the closest match to that of the non-anchor node to be the estimated location of the non-anchor node. However, compared with distance-estimation based techniques and RSS based techniques produce relatively small location estimation errors. Several area-based localization algorithms were proposed by Elnahrawy et al., (2004). These algorithms are area based because instead of estimating the exact location of the non-anchor node they simply estimate a possible area. Ni et al (2003), introduced weighted version of the RSS based localization technique which achieves a more accurate location estimate.

2.3 Multi- hop Localization

Multi-hop localization in cluttered environments can yield significant improvements in localization accuracy. Hussain and Trigoni.,(2010) proposed the use of 'localizers' for enabling better localization accuracy in the presence of clutter between the references and un-localized nodes Localizers help these nodes to localize more accurately than they would in case of single-hop localization which will involve distance measurements with large NLOS(non-line-of-sight) errors.. Drake and Dogancay (2004), proposed a solution for localization of distant transmitters based on triangulation of hyperbolic asymptotes. Hyperbolic curves are approximated by linear asymptotes. Solution exhibits some performance degradation with respect to the maximum likelihood estimator at low noise levels but outperforms the maximum possibility estimator at medium to high noise levels.

Distance vector -Hop localization technique introduced by Ibrahim *et al.,* (2013).In this technique the anchor node broadcast their actual positions to the Sensor Node. Sensor Node keeps the shortest number of hops to each anchor node along with the anchor node's position. It exchanges the shortest hop position messages only with their neighbours. While an anchor node receives a position message from other anchor nodes it estimates the average distance for a single hop for the entire network. Then the anchor nodes broadcast their estimates of the average distance for a single hop. Tang *et al*., (2013) proposed Cramer-Rao Bound analysis (CRB) analysis can be applied to both centralized and distributed localization algorithms to determine the unknown nodes' locations. In the CL-refine algorithm, local refinement is used, that is the locally available distances between any two neighbouring nodes are also reported to the sink for location estimation.

2.4 Distance based Sensor Network Localization

Robust distributed localization of sensor networks with certain distance measurement errors criteria was explained by Moore *et a*l., (2004). Robust distributed localization is selection of the sub graphs of the representative graph of a network to be used in a localization algorithm robust against such errors. However, is not complete and there may be other criteria that may better characterize robustness of a given sub-network against distance measurement errors. A node further away from anchor nodes is likely to have a larger location estimation error, since its location estimation error is not only affected by the distance measurement errors to its neighbours also affected by the location estimation errors of its neighbours using which the node's location is estimated. No of simulations and experimental studies suggested that in addition to distance measurement error, error propagation (as well as location estimation error) may be affected by node degree, network topology, and the distribution of both non-anchor and anchor nodes was developed in Ihler *et al*.,(2005). Savvides *et al*., (2005), proposed Cram'er-Rao bound and simulations to investigate the error characteristics for a specific scenario in which anchors are located near the boundary of the region and non-anchor nodes are located inside the region. The aforementioned flip ambiguity and discontinuous flex ambiguity problems make such validation particularly complex. The estimator may produce an unbiased estimate in one topology (e.g., a dense network with high node degree) but give a biased estimate in another topology (e.g., a spare network with low node degree).Most of the works previously achieved and validated for node localization remain as motivation for the design of MCL technique, whereas RSS, GPS and triangulation serve as parts of the proposed strategy.

3. Results and discussion

In wireless underground sensor networks, the nodes need to update their location information at regular intervals to ensure the communication between the nodes in the network. Many protocols use distance between the nodes as one of the criteria for multi-hop communication in the network. There is the need to know the location of the nodes and the distance between the nodes in many power optimization protocols. But the question of how to obtain the distance or the location arises in the same.

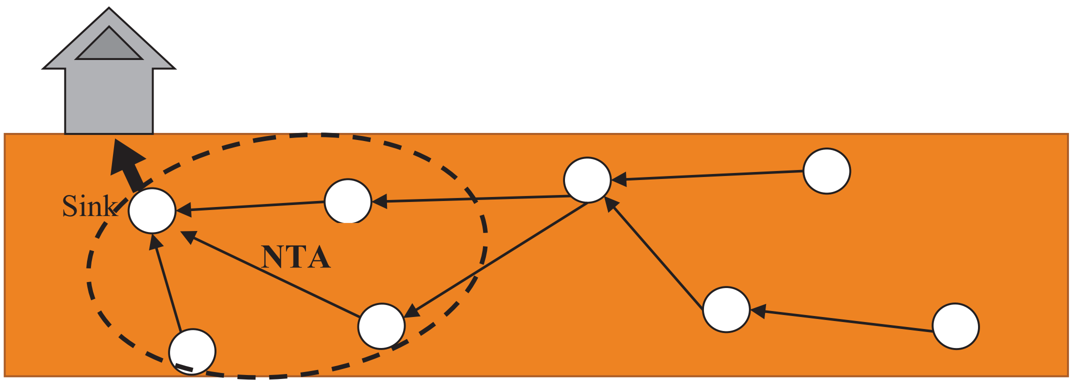

Fig 2. Network Topology in Subterranean Sensor Networks

Clearly, this protocol is a solution for determining the location of nodes to catalyze communication in the underground sensor networks. Initially there is a group of nodes deployed in the underground areas all of which connect to a sink that is further connected to the Base Station (Control Room). It is possible to locate all the nodes through GPS which can be used as a reference in the worst case scenario by the Base Station. The sink node has a Node Transmission Area (NTA) within which a node can be directly recognized by the sink node. In other words, direct communication is only possible with the nodes present within NTA as shown in the Fig 2. Each sensor node has a processor in which there is a separate memory that contains the co-ordinates of the sensor node which is updated and fine tuned after every communication process with its neighbouring nodes. The MCL methodology used to achieve localization and hence communication is explained below: The sink node *S* is capable of supplying the GPS information of every node $n \in V$ if required for reference purposes within the nodes randomly deployed that form the graph *G (V,E)* with *V* vertices and *E* edges.

Step 1: Start

Step 2: The sink node *S* finds the nodes present within the NTA by broadcasting a pilot signal which is acknowledged by only the subset of nodes $S(V_{NTA}, E_{NTA})$.

Step 3: The RSS values of the nodes within $S(V_{NTA}, E_{NTA})$ are measured to obtain the distances to the sink node *S*.

Step 4: Sink node S uses the Cartesian co-ordinates of the nodes within $S(V_{NTA}, E_{NTA})$ to obtain the angle between line joining the sink S and the nodes (say A and B, as in Fig.3).

Step 5: The sink now computes the distance between the adjacent nodes (d_{AB}) and transmits to the corresponding nodes.

Step 6: The nodes within NTA update their tables with their distances to their neighboring nodes.

Step 7: A node *i* from the NTA now becomes the arbitrary sink for the next set of neighbors from the subset $S(V_{NTAi}, E_{NTAi})$

Step 8: Go to Step 2 until all nodes know their distances and angles and have their neighbor tables updated.

Step 9: Stop.

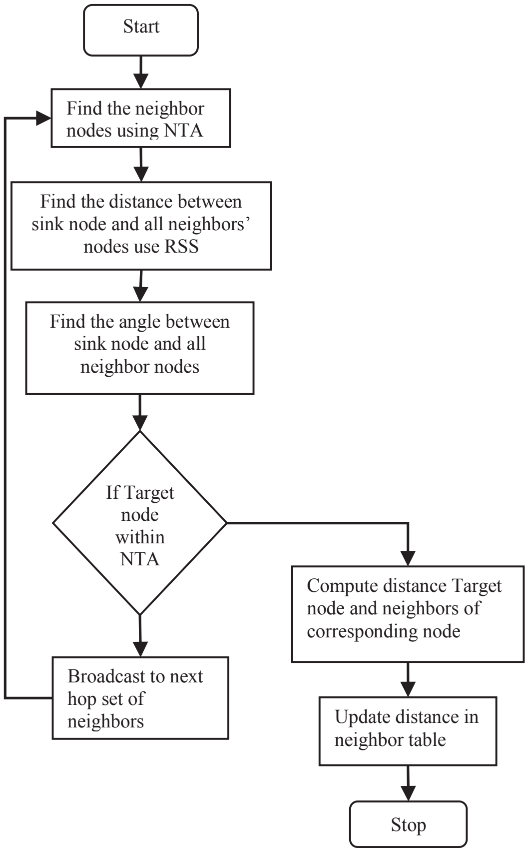

Fig.3 Flow diagram of proposed system

Figure 4 shows that the nodes A and B belong to the subset $S(V_{NTA}, E_{NTA})$. According to the proposed strategy, the distances d_{SA} and d_{SB} are obtained from the RSS values of the acknowledgments received from A and B after the sink node sends a Pilot Signal using distance equation (1). The Cartesian co-ordinates of A and B are obtained from the GPS values stored by the sink are used to find the angles A makes with the line SB computed as $\angle BSA$ using equation (2).

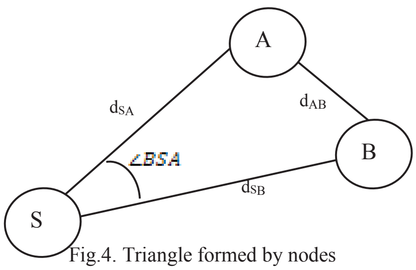

Fig.4. Triangle formed by nodes

$$d = \sqrt{(x - x_1)^2 + (y - y_1)^2} \quad (1)$$

Where x and x_1 are the co-ordinates of the two nodes between which distance d is estimated.

The two Cartesian co-ordinates of S and A are obtained using the GPS (4). This makes an angle $\angle OSA$ with an arbitrary line SO. Similarly, $\angle OSB$ is formed by obtaining the slope of the line SB formed by the individual co-ordinates of S and B. By obtaining these values the required angle $\angle BSA$ is obtained as a difference between the two angles as in equation (4).

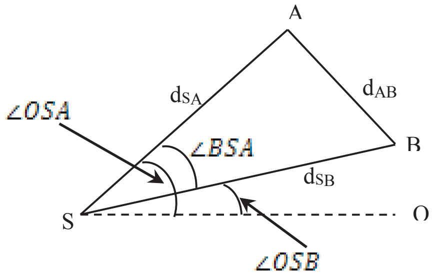

Fig.5. Estimating angle from nodes

Angle between two lines joining S and A with corresponding co-ordinates x_s, y_s and x_a, y_a can be given by substituting equations (2) in (3),

$$dx = x_s - x_a$$
$$dy = y_s - y_a \quad (2)$$

$$angle = \text{Atan}\,2(dy, dx) \times \frac{180}{\pi} \quad (3)$$

$$\angle BSA = \angle OSA - \angle OSB \quad (4)$$

Having known the angle $\angle BSA$ and the distances d_{SA} and d_{SB} it is possible to obtain the third side using the law of cosines, which is an extension of the Pythagoras theorem as in equation (5).

$$c^2 = a^2 + b^2 - 2ab\cos\theta \quad (5)$$

Hence according to our system model, the equation (5) can be rewritten as,

$$d_{AB}{}^2 = d_{SA}{}^2 + d_{SB}{}^2 - 2d_{SA}d_{SB}\cos\angle BSA \quad (6)$$

Thus the distances of all the nodes in the network can be estimated and their co-ordinates updated when this process continues for all nodes.

3.1 Data Transmission

The above mentioned process is consecutively progressed from the Sink Node's NTA until all other nodes in the network are discovered and located. For every communication process, a node in the current NTA becomes the sink for the next set of nodes.

The known position of the target T is obtained from the sink through the GPS co-ordinates. As shown in the Fig. 6, the shortest route to the target nodes from the sink is *Sink-a-h-T*, which means h is the last intermediate hop before the target in the route. The nodes in the neighbor list of this intermediate node h find the distances to the target node. To achieve this, only once the GPS co-ordinates of T are used to measure the distance d_{HT} and this is used along with d_{HG} and the angle $\angle GHT$ to find the distance of target *T* from the node *g* (d_{GT}).

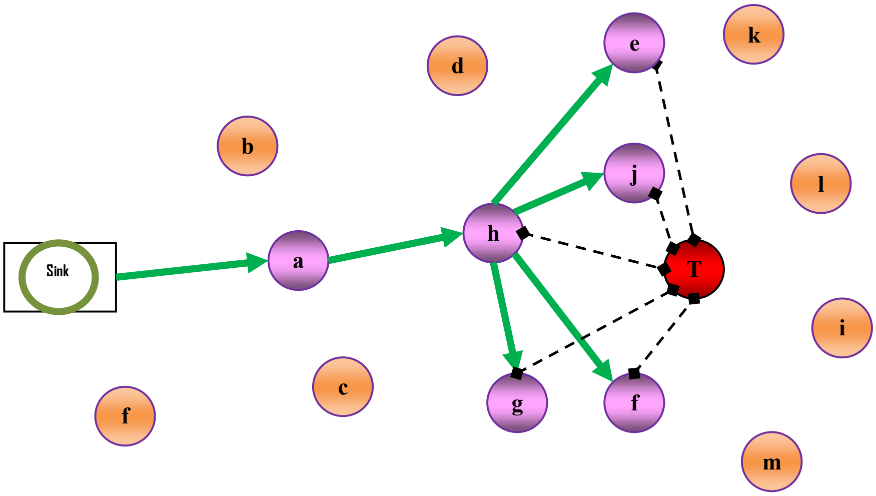

Fig.6. Localization of a Target

Similarly, all nodes that can sense the signals from T estimate their distances to the target T and report to the base station using which the target can be ultimately localized. In other words, this technique is an attempt to use RSS and triangulation hop by hop to both localize and communicate to the subterranean sensor nodes present in the network. To validate the method proposed here, a simulation scenario with 30 nodes deployed and configured as the subterranean wireless network is used with the specifications mentioned in the Table 1. Programming in C++ and Object-oriented Tool Command Language (OTCL) is done to determine the locations of various targeted nodes.

Table 1. Simulation Parameters

Parameter	**Value**
Number of nodes	30
Routing protocol	DSDV
Traffic model	CBR
Simulation Area	1500 x 700
Transmission range	250m
Antenna Type	Omni antenna
Mobility model	Two ray ground
Network interface Type	WirelessPhy
Channel Type	Wireless channel

Since this is a unique approach, simulations are performed analyze both communication efficiency and accuracy of localization. A number of experiments were conducted to find a target and then obtain the data sensed by the target node functioning together as a network. At every execution, various target nodes are entered to find distances between the nodes around it using the MCL technique proposed here. The difference in the distances is a metric to know the efficiency of the localization.

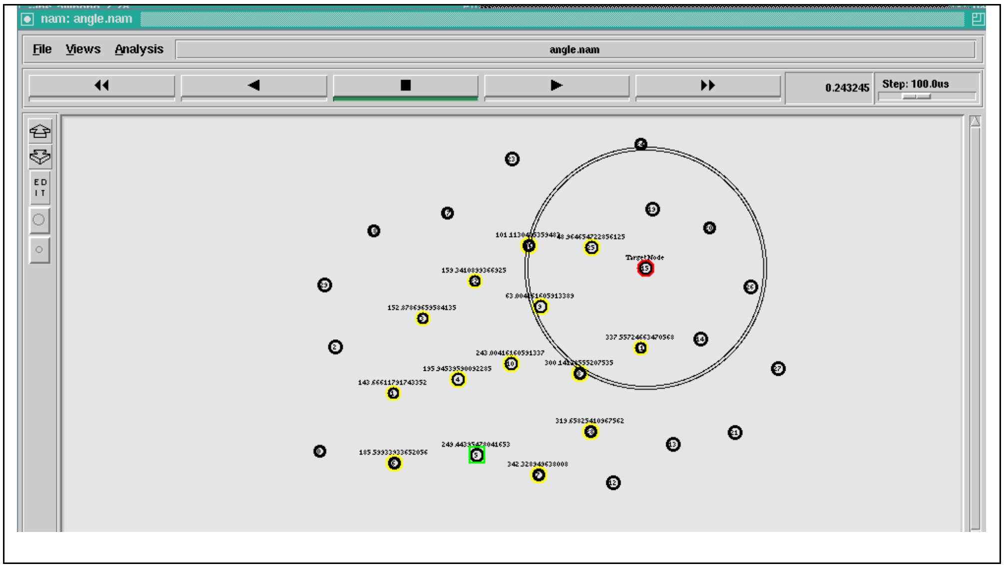

Fig 7. Simulation Experiment Scenario of MCL

Table 2. Computational Distance and Actual Distances from the target

S. No.	Target Node	Neighbour Node	Computational Distance (m)	Actual Distance (m)	Difference in Distances (m)
1	6	4	195.2338354	194.8050307	0.4288046
2	6	1	129.3155654	129.0155029	0.3000625
3	15	8	228.6491143	229.1724241	0.5233098
4	15	9	206.4032894	206.2425756	0.1607138
5	15	11	145.1402167	146.342065	1.20184834
6	15	16	220.4270334	220.0454499	0.3815836
7	15	19	108.8839467	108.7795937	0.1043531
8	15	25	107.2295191	106.976633	0.2528861
9	25	9	143.5017433	143.1782106	0.3235326
10	25	22	224.9628883	224.7220505	0.2408378
12	25	23	96.33319893	96.13012015	0.2030788
13	29	4	226.0095255	225.8583627	0.1511628
14	29	1	201.7847627	201.434853	0.3499097
15	29	17	181.4084862	181.1077027	0.3007834
16	29	18	98.80436726	98.73196038	0.0724069
17	29	22	174.4236082	174.1034175	0.3201907
18	29	2	140.6904705	140.4279175	0.262553
19	5	6	154.0756376	153.7333536	0.3422841
20	5	10	178.3950405	179.4240787	1.02903819
21	5	1	192.8026961	192.4084198	0.3942763
22	5	24	113.9879838	113.7013632	0.2866206

Fig.7 represents the scenario considered for the simulation performed. Experimental results of the simulation model with the above specifications are shown in the Table 2. Here, the distances to the neighboring nodes from the target are measured both computationally and directly using the distance formula. The Table 2 shows that there is minimal variation in the distances obtained computationally and actually.

The differences in the distances obtained are plotted in the given Fig.8 below, which shows the efficiency of this method. On a minimum there is 0.161 m difference in distance estimated by the computational method from the actual distances from the target to their neighbouring node. The maximum difference in distance is 1.029m which leaves an average difference in distances as 0.363.

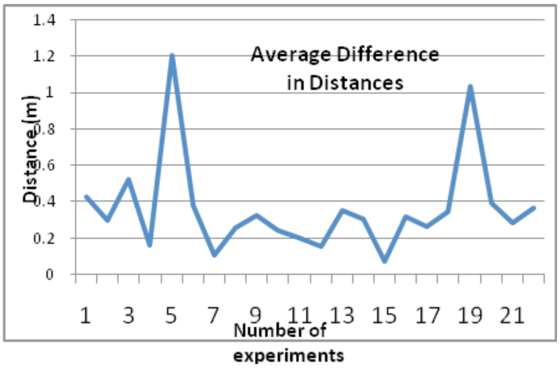

Fig.8. Average Distance Variations

Throughput of the messages MCL is measured to ensure that the normal working of the sensor network is not interrupted by the working of the localization method proposed here. Throughput is the total number of packets successfully received at the receivers over the simulation period. Fig. 9 shows that there is good throughput across the network.

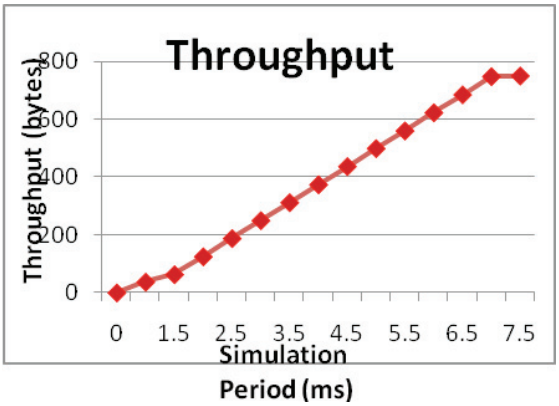

Fig 9. Throughput

If the target node present in NTA, the sink sends the data directly otherwise the sink sends the data through multiple hops. Figure.10 shows that the hop count increase also the distance will be increase.Fig.11 shows that distance Vs time. If the target node exist NTA, the target node receives the data instantly. Otherwise the sink sends the data through multiple intermediate nodes until reach the target node. So the time increase or decrease based on the distance.

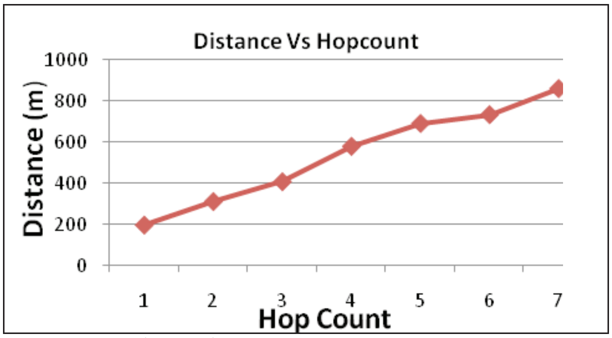

Fig.10. Distance Vs Hop count

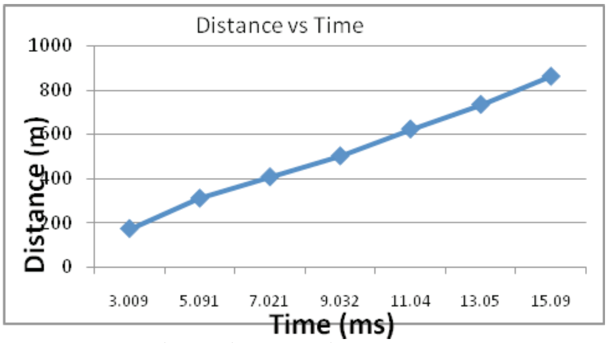

Fig.11. Distance vs Time

Conclusion:

It can be observed from this method that the target localization can be achieved by using the angles and the distance method to achieve good accuracy. Clearly from this method the network throughput is not affected. The advantage of this method is that the regular updating at every node gives greater accuracy over redundant data transmission and localization. This method can be extended to suit other applications as well. The MCL method can hence help in localization of a target node and also help in the communication of sensed information back to the base station with good throughput. A combination of MCL with the other localization techniques like DV-hop and DV-distance can be worked out for future work.

References

1. .Bahl.P and Padmanabhan.V., 2000.RADAR: an in-building RF-based user location and tracking system, in IEEE , 2, 775–784.
2. Capkun,S, Hamdi, M and x Hubaux J.P., 2001.GPS-free positioning in mobile ad-hoc networks. In HICSS.
3. Drake.S and Dogancay.K.,2004. Geolocation by time difference of arrival using hyperbolic asymptotes, in IEEE International Conference on Acoustics, Speech, and Signal Processing, 2, ii–361–4.
4. Elnahrawy.E, Li.X., and Martin.R,2004.The limits of localization using signal strength: a comparative study, in First Annual IEEE Conference on Sensor and Ad-hoc Communications and Networks, 406–414.
5. Hussain.M and Trigoni.N.,2010. Distributed localization in cluttered un-derwater environments, Proceedings of the Fifth ACM International Workshop on UnderWater Networks, 1–8.
6. Ibrahim, Walid M., Hossam S. Hassanein, and Abd-Elhamid M. Taha.,(2013), Does multi-hop communication enhance localization accuracy?, IEEE Global Communications Conference (GLOBECOM), 121-126.
7. Ihler, I. Fisher, J.W., Moses R., and Willsky A., 2005. Nonparametric belief propagation for self-localization of sensor networks, IEEE Journal on Selected Areas in Communications, 23(4), 809– 819.
8. Moore D, Leonard J, Rus D, and Teller S., 2004.Robust distributed network localization with noisy range measurements, in the 2nd ACM Conf. on Embedded Networked Sensor Systems,50–61.
9. Ni L. M, Yunhao L., Yiu L, Cho, and Patil A. P., 2003.LANDMARC: indoor location sensing using active rfid,in Proceedings of the First IEEE International Conference on Pervasive Computing and Communications,407–415.